AD-A156 583 SOLAR FLARES AND MAGNETOSPHERIC PARTICLES: INVESTIGATIONS BASED UPON THE..(U) LOUISIANA STATE UNIV BATON ROUGE DEPT OF PHYSICS AND ASTRONOM.. J P WEFEL 1/1

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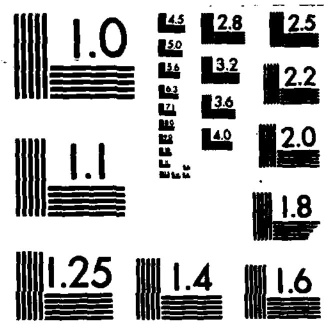

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ANNUAL LETTER REPORT

ONR Contract N00014-83-K-0365

"Solar Flares and Magnetospheric Particles:

Investigations Based Upon the ONR-602 Experiment"

John P. Wefel
Principal Investigator

Covering the Period: 4/1/84 - 6/30/85

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28 June 1985

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SOLAR FLARES AND MAGNETOSPHERIC PARTICLES: INVESTIGATIONS BASED UPON THE ONR-602 EXPERIMENT

ONR Contract N00014-83-K-0365

I. INTRODUCTION:

The report covers the second year of the contract, cited above, which involves fundamental investigations of the charged particle component in the Geospace environment. The project involves analysis of the data returned from the ONR-602 (Phoenix-1) experiment on the S81-1 mission, correlation of the Phoenix-1 dataset with other measurements and scientific planning for the launch and operation of a "sister experiment," ONR-604 on the CRRES mission. During the past year significant progress was made in understanding the ONR-602 instrument performance and the dataset, in analyzing the low-energy protons observed in the equatorial belt, in the study of solar energetic particles in the magnetosphere, and in working with the CRRES SPACERAD Science Team.

II. Personnel:

The personnel engaged in this analysis effort remain the same as in the first contract year. In addition to the principal investigator, one graduate student, Mr. M. A. Miah, worked full-time on the project; a Senior Research Associate, Dr. T. G. Guzik worked part-time on the analysis; a programmer/analyst, Mr. M. Jacobson was involved part-time with the data handling tasks; and several undergraduate students were employed to help with routine tasks.

III. Facilities:

The majority of the data analysis tasks are handled with a small PDP-11/73 based data processing system in the High Energy Astrophysics/Space Science group at LSU, augmented by the use of the university's SNCC IBM 3081 mainframe computer system. In the past year a VAX-11/750 based Experimental Physics Data System (EPDS) has become available to the High Energy Astrophysics/Space Science group, and some of the analysis tasks have been transferred to this system. The EPDS vastly improves compatibility with the data analysis system at the University of Chicago, with which we interact, and enhances the data analysis capabilities which can be applied to this project.

IV. Administrative Actions:

On 22 March 1985 a No-Cost Extension was requested through 30 June 1985 to make it possible to continue our work with the CRRES program following the original termination date of 31 March 1985. This extension was granted 3 April 1985. Therefore, this report covers the period 1 April 1984 to 30 June 1985.

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V. Reports and Presentations:

No papers were published in journals during this period but a number of reports and presentations covering our work were prepared as:

(1) "The Experiment for High Energy, Heavy Nuclei Composition (ONR-604)," J. A. Simpson, M. G . Munoz, M. Perkins and J. P. Wefel, in "CRRES/SPACERAD Experiment Descriptions," Air Force Geophysics Laboratory publication.

(2) "Galactic Cosmic Ray Isotopes and Elements: An Overview," John P. Wefel, an invited talk presented to the CRRES/SPACERAD Science Team Meeting, AFGL, October 1984.

(3) "Investigations of Solar Charged Particles: The Phoenix-1 Experiment," T. Gregory Guzik, presented at the Workshop for a High Energy Facility for Solar Physics, University of New Hampshire, October 1984.

(4) "Observations of 0.5 - 9 MeV Protons at Low Altitude in the Equatorial Radiation Belt during 1982," A. Miah, T. G. Guzik and J. P. Wefel, Bull. Am. Phys. Soc., 30, 778 (1985).

(5) "Solar Flares and Magnetospheric Particles," John P. Wefel, presented at the Space Environment and Communications Workshop sponsored by ONR, University of Chicago, 16-17 May, 1985.

VI. Scientific Results:

(Phoe. x 1)

The work performed during the past year can be divided into three areas: (i) Data Reduction/processing and instrument response, (ii) Solar flare studies, and (iii) Magnetospheric particles. Our analysis effort has been divided between obtaining an overview of the entire ONR-602 dataset, identifying data processing/analysis problems and locating scientifically interesting effects for additional study, and studying specific areas or problems of scientific/technical interest. This dual approach is necessary to fully understand the operation of the ONR-602 instrument in the space environment and the complicated particle flux variations over the the spacecraft orbit.

(A) Data Reduction/Processing and Instrument Response:

In this area, attention has been focussed on refining our knowledge of the instrument performance and response during the mission and on identifying, understanding and resolving some of the conflicting data blocks on the Phoenix-1 CHART tapes.

The sheer volume of data returned from the ONR-602 experiment required the development of a software plotting library (to which routines are still being added) and extensive data checking. In the latter area, problems with spurious rate readouts and with "fill" data (there was, in general, missing periods of time from each orbit due to the power availability on the spacecraft) were uncovered and software was developed to deal with these problems. Simultaneously, sections of the data were analyzed scientifically, which revealed additional anomalies on the data tapes. This on-going effort

to understand the data tapes is being coordinated with the Chicago analysis team who have been able to trace many of the anomalies into the original data tapes. We expect to receive an updated set of raw data tapes (the PHRET tapes) in the near future, and this should simplify the task of tracing and understanding anomalies in the data.

To understand the ONR-602 counting rate data, it is necessary to determine the instrument response to the particle fluxes encountered in space. This can only be done from the data itself, and a portion of our effort has been directed to this goal. The two ONR-602 telescopes (main system and monitor system) return three types of counting rate information, the low energy monitor telescope rates (ML, MM, MH), the main telescope coincidence counting rates (RD1-RA) and the main telescope singles counting rates (D1S-SS). With the nominal detector thresholds (D1, D2 = 2 MeV; T_1, T_2, T3 = 4 MeV; K1, K2 = 1 MeV; A = 0.25 MeV; S = 0.5 MeV and Monitor thresholds of 0.35, 2.5, and 10 MeV), the particle species and approximate energy ranges (at 15° incidence angle) sampled by the different rates are given in Table 1:

TABLE 1

Counting Rate	Particle Species	Energy (MeV/n)	Counting Rate	Particle Species	Energy (MeV/n)
ML	$\geq$ P	0.5 - 9	D2S	Calibrator	
				He	~2 - 8.5
MM	$\geq$ He	0.8 - 4.5	T1S	Calibrator	
				He	~3.5 - 14
MH	$\geq$ Hi-Z(^{12}C)	1.1 - 11	T2S	P	~7 - 9.5
				He	~6 - 33.5
RD1	Calibrator		T3S	P	~10 - 15
	He	~0.5 - 8		He	~9 - 60
	P(large angles)	~2 - 2.5	K1S	P,He	$\geq$12.5
RD2	He	~2.5 - 8	K2S	P,He	$\geq$34.0
RT1	He	~3.5 - 8	AS	P,He	$\geq$48.0
RT2	He	~5.5 - 8	SS	electrons	$\geq$0.85
RT3,RK1,RK2,RA	Z>2				

The energy ranges quoted in Table 1 are still approximate and do not include any indication of background effects. The main telescope contained a radioactive source, in-flight calibrator which was utilized to monitor the operation of detectors D1, D2 and T1. This calibrator provides a fixed background level for the singles rates from these detectors (and rate RD1). In addition, the singles rates involve particles incident from many different angles and therefore show a large background counting rate. Note that the instrument is relatively insensitive to low energy protons, except for the monitor ML rate, but can study Helium nuclei and heavy ions from energies of about 1 MeV/nucleon upward. Many of the results discussed below are derived from analysis of the low energy monitor counting rates, ML, MM and MH.

(B) Solar Flare Studies:

Figure 1 shows the major solar flares available for study by the ONR-602 experiment on the S81-1 mission. Plotted is the intensity of interplanetary protons >10 MeV as recorded by the GOES monitoring satellites. Note that the July, 1982 period was the most intense flare period available for study.

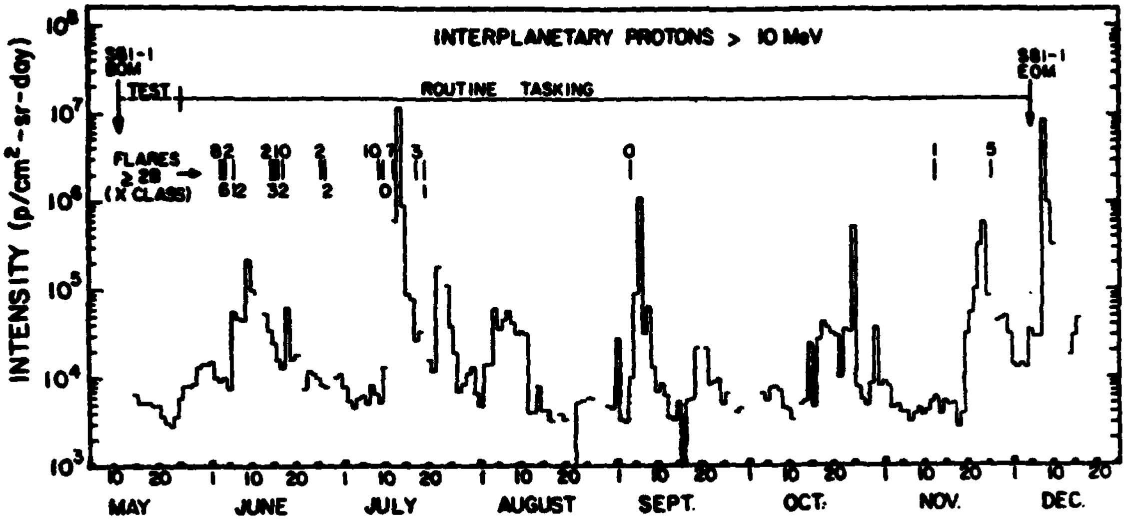


Figure 1. Solar flares during the S81-1 mission.

Studying the detailed isotopic composition of the flare particles requires analysis of data from the main telescope. For pulse height analysis, each particle must penetrate to detector T2, giving measurements over the approximate energy range 10-40 MeV/nucleon. Figure 2 summarizes the ONR-602

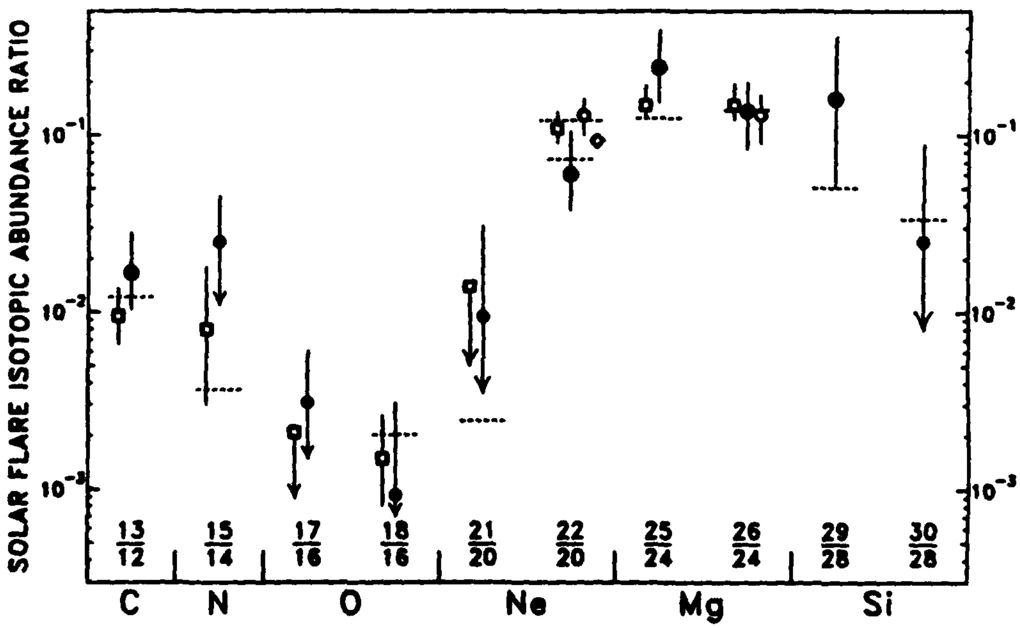


Figure 2. Solar flare isotope results.

solar flare isotopic composition measurements from summing the individual flares shown on Figure 1. Selected ratios from this experiment (●) are compared to earlier data from Chicago (○-Dietrich and Simpson, 1979; 1981) and Cal Tech (□-Mewaldt et al., 1983) and to the composition of the solar system -- dashed line (Anders and Ebihara, 1982). Note that there is an overall agreement between the different solar energetic particle experiments and between the experimental results and the solar system composition as derived from measurements in meteorites. This implies that there is little perferrential acceleration based on particle mass or rigidity during the explosive phase of a solar flare. Unfortunately, for many of the important "tracer" isotopes (^{17}O, ^{21}Ne, $^{29,30}Si$, the iron isotopes) there are insufficient numbers of events recorded, due to the small size of the flares, to make a meaningful measurement.

An element of particular interest is neon for which the results are shown in more detail on Figure 3. In the solar system there are several components of neon that have been identified based upon the isotopic ratios. Ne-A is observed in carbonaceous chondritic meteorites and is believed by some to represent the primordial composition (Cameron, 1982). Ne-B is found implanted in the surface of meteorites or lunar samples and is believed to be almost the composition of the neon carried by the solar wind. Ne-C is believed to be implanted in lunar samples by solar flare particles (Black, 1983). The available isotopic measurements do not resolve this problem due to the limited statistical accuracy. A weighted average of the three measurements on Figure 3 would be most consistent with Ne-C but cannot firmly exclude Ne-A or Ne-B as the flare composition. The question of the exact neon composition in the Sun will require additional data, possibly from the ONR-604 instrument on the CRRES mission or from a new mission for an instrument such as Phoenix-1.

Another interesting investigation is the search for the signature of neutrons produced during a solar flare. These neutrons will decay in-flight and have been observed as a pulse of protons in interplanetary space. The arrow on Figure 4 shows the neutron "signature" as observed from the ISEE spacecraft (courtesy P. Evenson) for the 3 June 1982 solar flare (Evenson et al., 1983). A similar signature might be observed in the ONR-602 data, and the lower part of Figure 4 shows expanded views of some of the ONR-602 rate data with the black triangle indicating the expected location of the protons from the neutron decay. Note

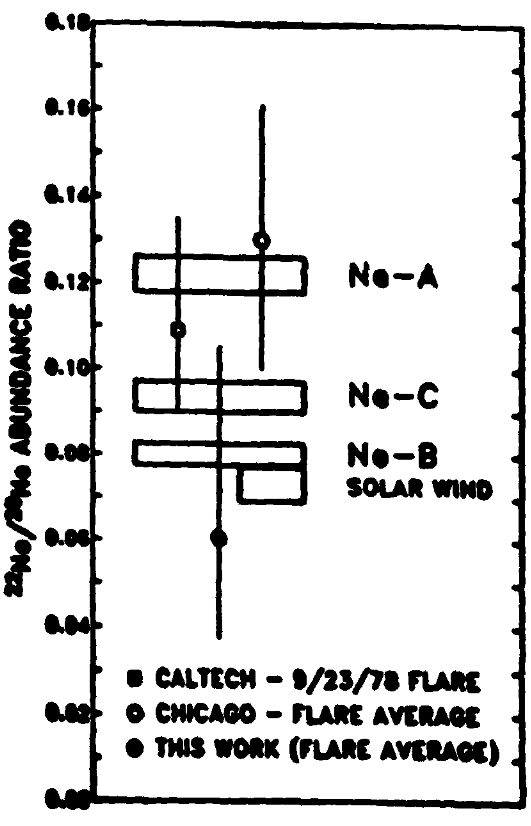


Figure 3. Neon Isotopic Composition.

SOLAR FLARE NEUTRON SIGNATURE

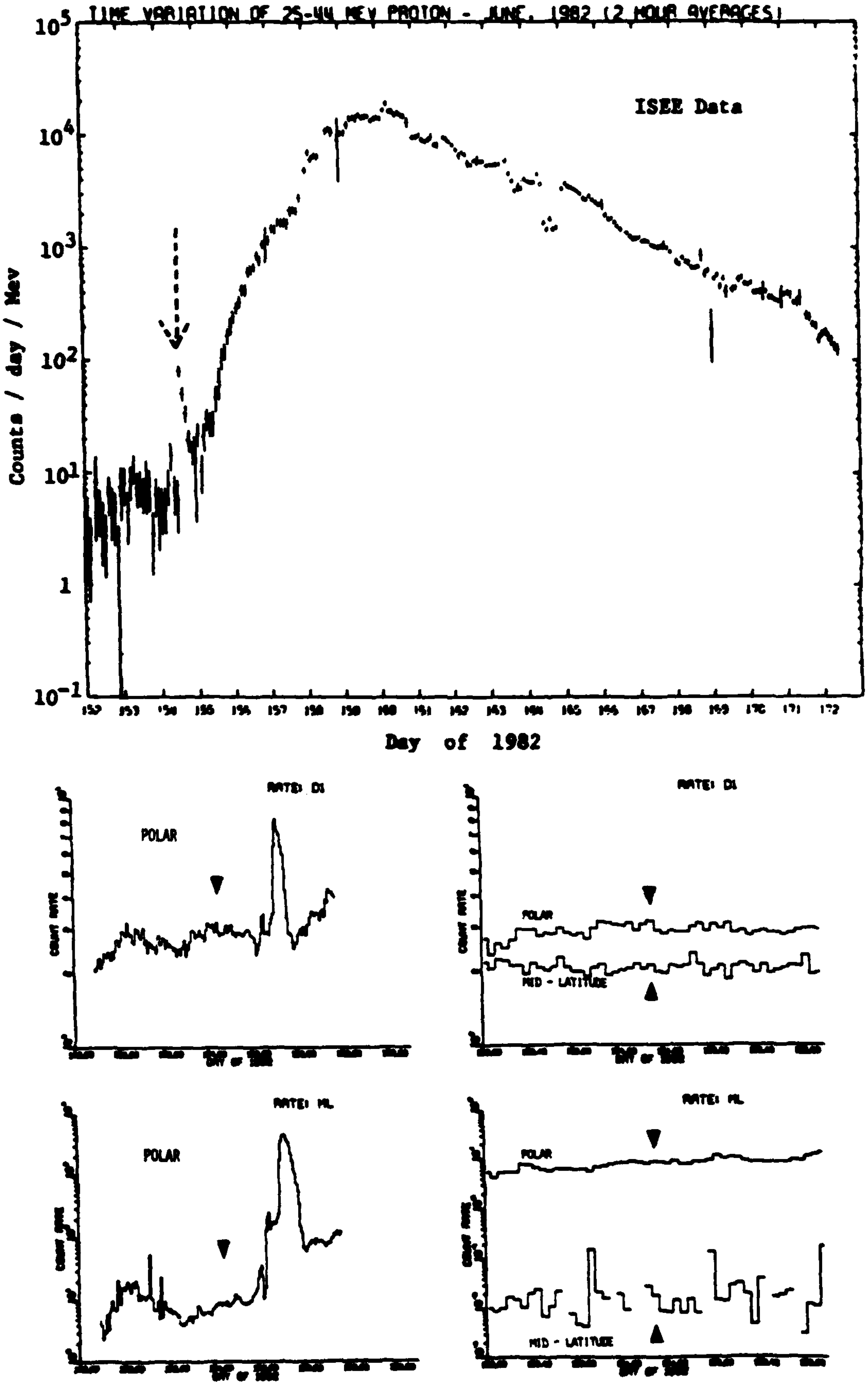


FIGURE 4

that there is no convincing peak in the counting rates, and we must conclude that these neutrons have not been observed.

The explanation for this null result for solar neutrons is inherent in the design of the ONR-602 instrument. As Table I shows the energy range for the particles studied by Phoenix-1 is too low to observe the neutrons, which were seen between 25-45 MeV in interplanetary space. In addition, the higher energy singles counting rates have too high a background to observe the small flux from this flare. However, the discovery of a pulse of protons corresponding to the neutron decay trapped or quasi-trapped in the Earth's magnetosphere would be an observation of great importance, since this would be a direct observation of the proposed neutron injection model for magnetospheric particles and would provide a measure of the solar neutron environment in space. Such an investigation should be possible with the higher energy ONR-604 instrument on the CRRES mission.

During the past year we have also begun to analyze the connection between solar flares and magnetospheric particles. Figure 5 shows, for the July, 1982 flare period, the time history of low energy interplanetary protons (from geosynchronous orbit), the ONR-602 instrument counting rates in the polar regions and the hourly DST magnetic field index. The instrument coincidence counting rates from RD1 through RT3 follow the same behavior, which correlates in time with the interplanetary flux. The arrival of these particles occurs just at the beginning of the depression in the DST index, but the maximum effect on the geomagnetic field is not observed until about a half-day after the peak particle fluxes. From the data examined thus far the causitive factor for the turbulence in the geomagnetic field and an explanation of the time delay have not been identified. Additional analysis, including a careful time history both before and after the peak particle fluxes, is needed to make further progress on this problem.

(C) Magnetospheric Particle Investigations:

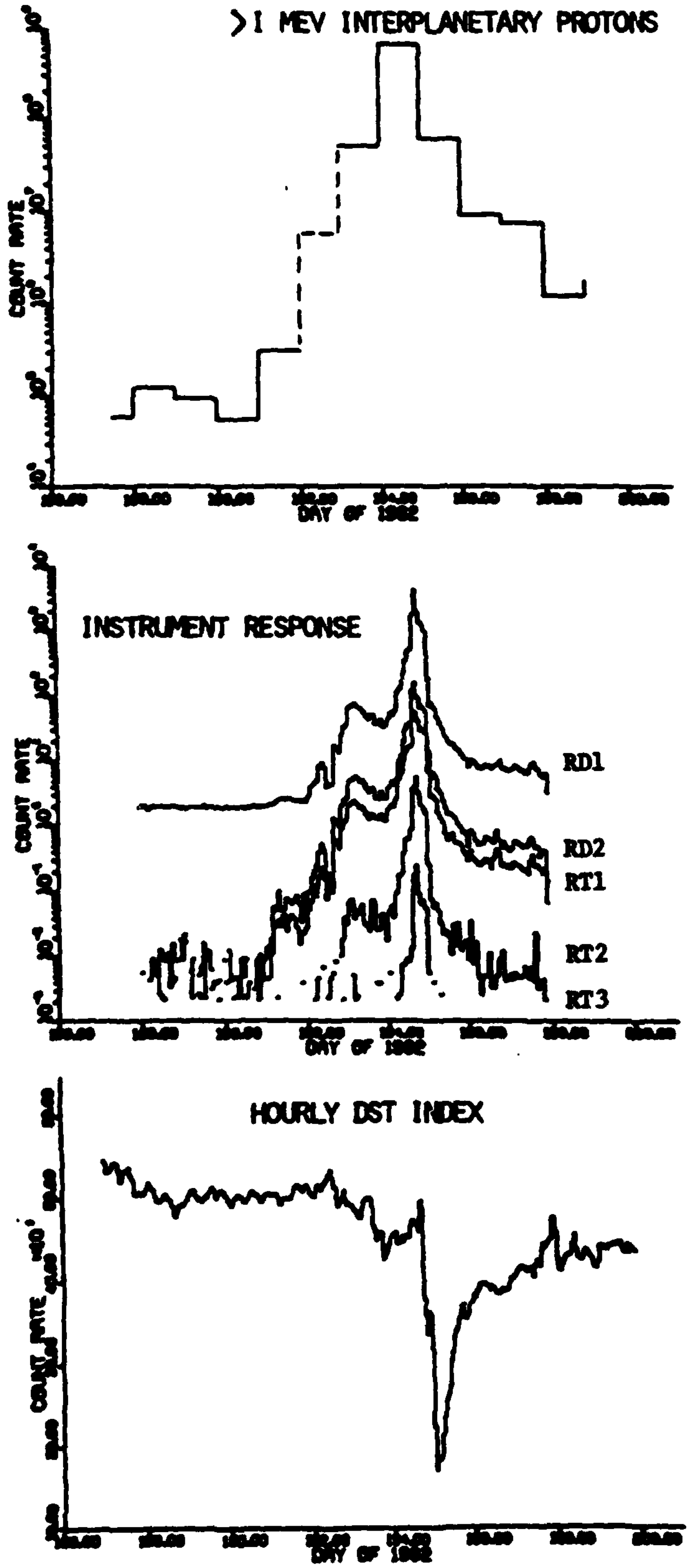
The connection between solar flares and geomagnetic disturbances shown in Figure 5 has been established for a number of years. A further aspect of this problem is the variation induced in the magnetospheric particle populations in response to such transient events. Figure 6 shows the time variation of particles recorded in the South Atlantic Anomaly (SAA) region, uncorrected for instrument data coverage, for medium energy electrons (top) and low energy protons (center) compared to the geomagnetic DST index. Neglecting the spikes in the ML rate (a bit error problem) there is a correlation between the two largest excursions in the DST index and subsequent increases in the level of protons and electrons observed in the SAA. Finer structure in the DST index, presumably corresponding to substorms, is not reflected in the protons and electrons for the two day averages shown.

The S81-1 mission provided global coverage, at low altitude, of the magnetosphere, and we have investigated the spatial structure of the data by means of global distribution plots. An example is shown on Figure 7 which compares the available coverage (1° x 1° bins -- a black spot indicates at least one readout in the bin) to the regions in which low energy protons (ML), low energy helium (MM) and medium energy electrons (SS) are observed. Other than the polar region, where solar flare particles are observed, the most pronounced features are the SAA (protons, alphas and electrons) and a "belt" of low energy protons following roughly the geomagnetic equator.

FIGURE 5

TIME DEPENDENCE OF FLARE PARTICLES

JULY 6 - JULY 18, 1982



TIME DEPENDENCE OF PARTICLES IN INNER MAGNETOSPHERE

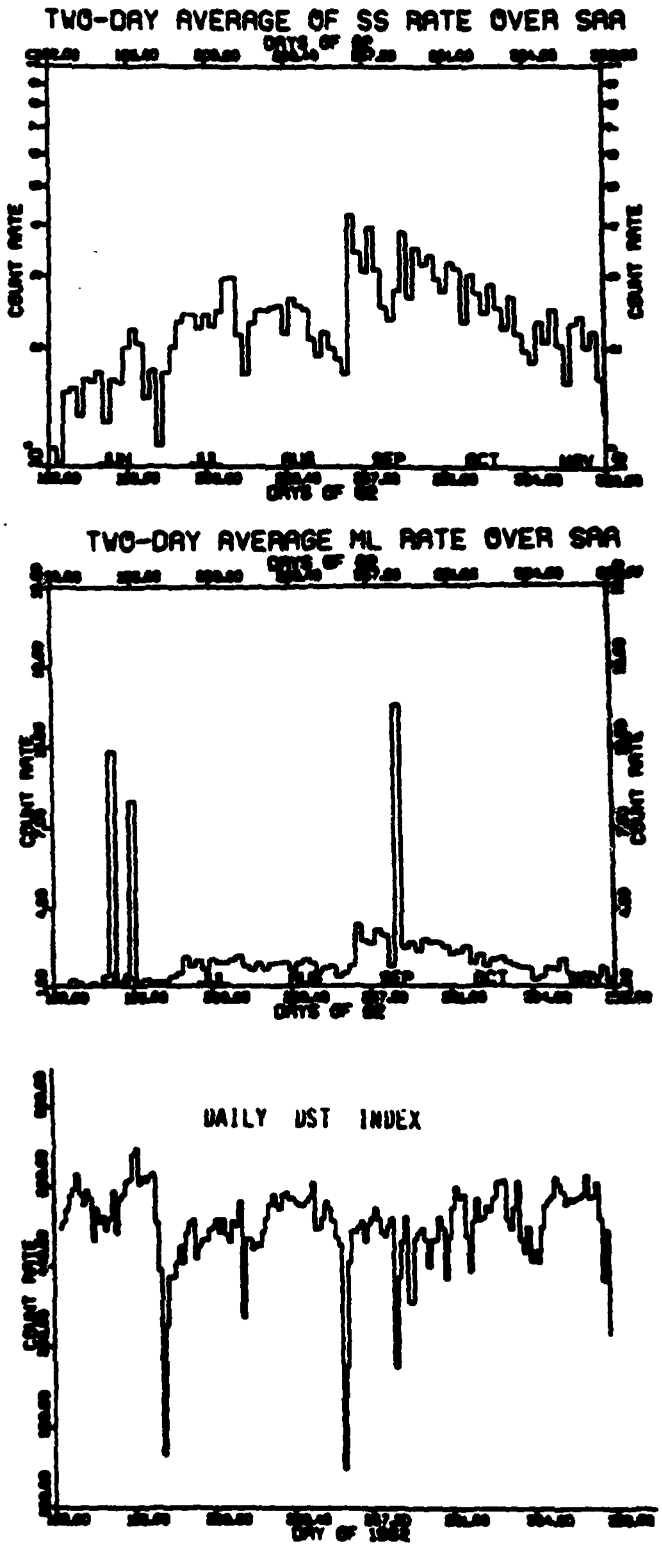


FIGURE 6

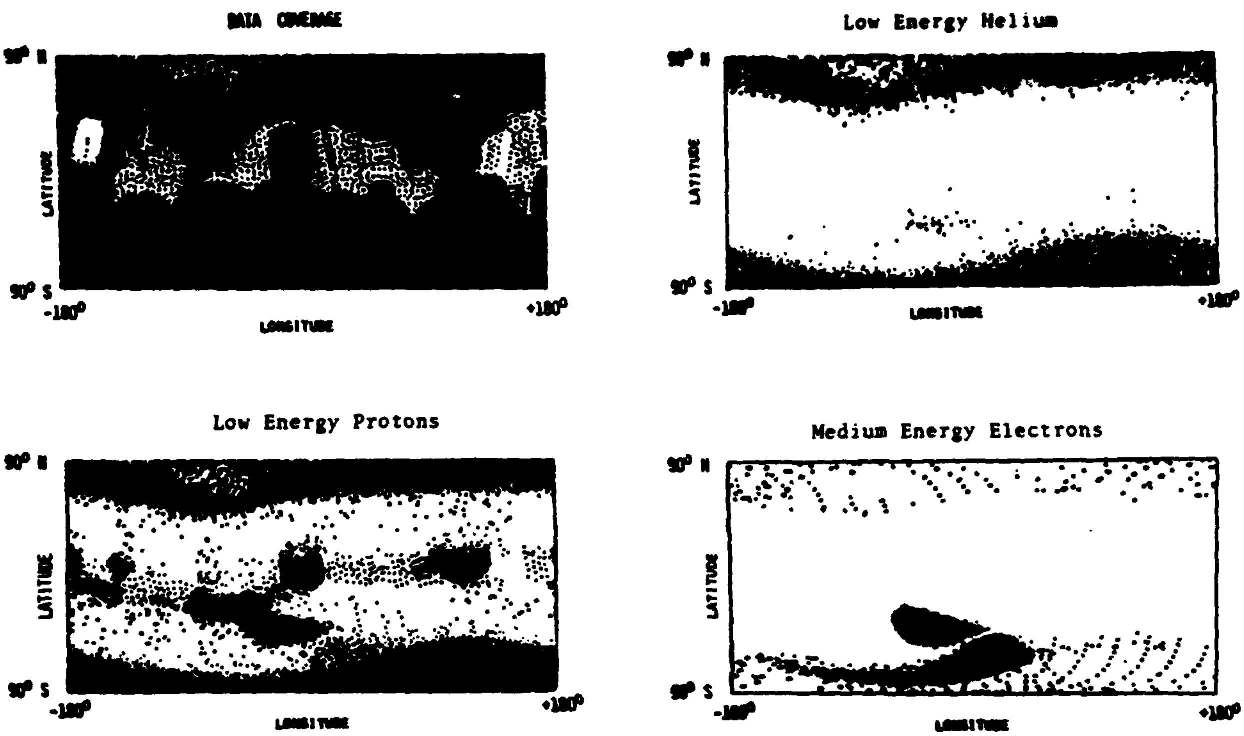
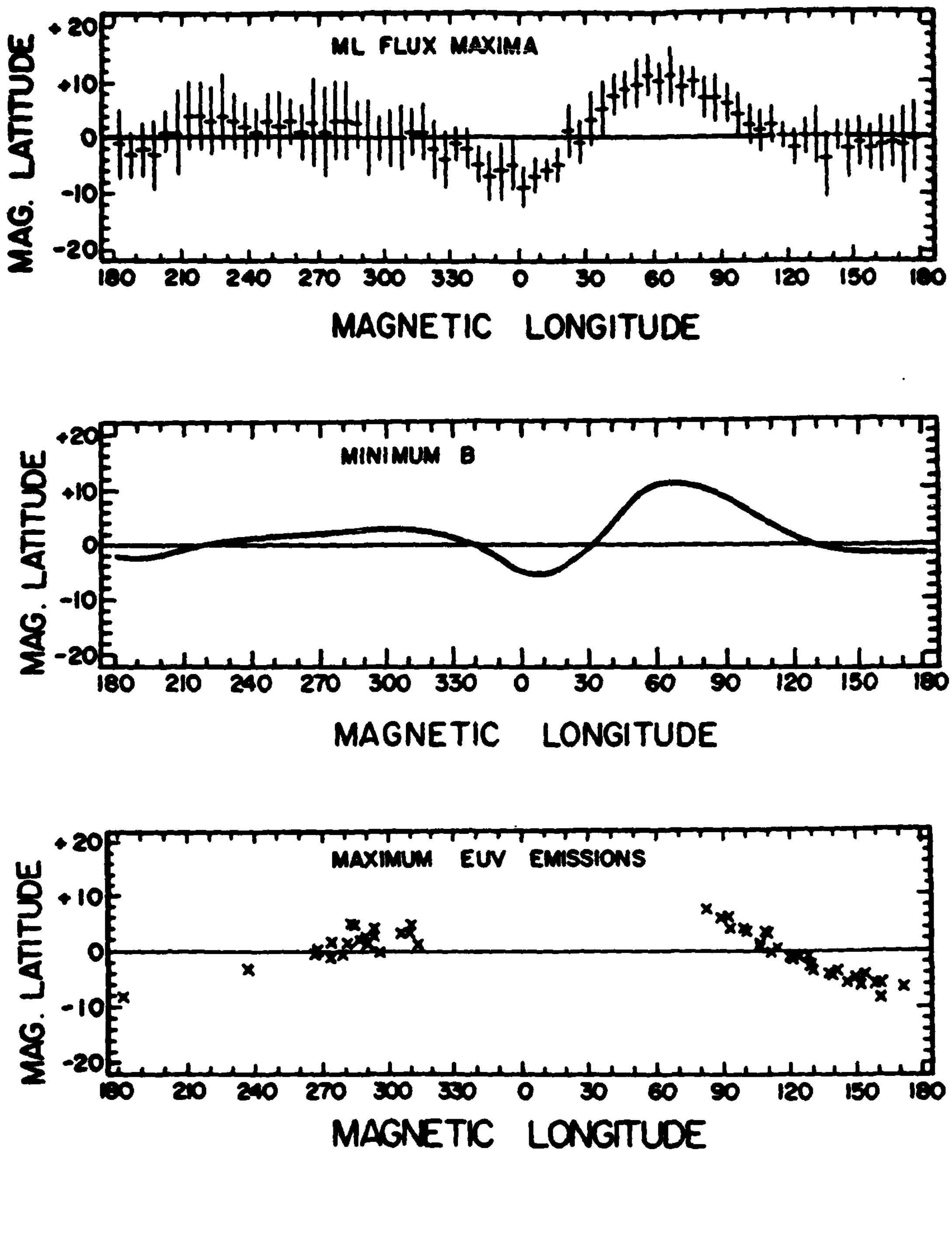


Figure 7. Global Distribution Plots

The equatorial belt protons have been observed previously in the late 60's/early 70's (Krassovsky et al., 1963; Heikkila, 1971; Hovestadt et al., 1972; Scholer et al., 1975; Berko et al., 1975) for energies generally in the keV range and were interpreted as to be a permament, albiet somewhat variable, component of the Earth's magnetosphere. The observations of this belt by ONR-602 at relatively high energy and by the SEEP experiment (also on the S81-1 spacecraft) at keV energies (Voss et al., 1984) in the 1982 epoch shows that this low altitude equatorial belt is, in fact, a permament part of the Earth's radiation environment.

The origin of this equatorial belt is traditionally ascribed to charge exchange on the particles in the ring current, leading to neutrals which diffuse downward until they are re-ionized in the thermosphere and become trapped in the lower magnetosphere. Various analyses (e.g. Moritz, 1972; Berko et al., 1975; Tinsley, 1976; 1979) have used this model to extrapolate measurements back to the ring current and to suggest the presence of alpha particles in this pseudo-belt. As Figure 7 shows, we do not find any signature for alpha particles at the energies sampled by the MM rate (see Table 1).

The global coverage provided by the S81-1 mission provided the first opportunity to study the location of this equatorial proton belt. The data were subdivided into 5° longitude bins and the latitude of the peak counting rate was determined. Figure 8 shows a plot of the results (top) compared to the location of the minimum B equator (center) and to the location of the maxima in extreme ultraviolet emissions (from He^+ presumably excited by the equatorial belt protons -- replotted from Meier and Weller, 1975). These results are all consistent with a maximum particle flux centered over the



ML FLUX MAXIMA
MAG. LATITUDE
+20
+10
0
-10
-20
180
210
240
270
300
330
0
30
60
90
120
150
180
MAGNETIC LONGITUDE
MINIMUM B
MAG. LATITUDE
MAGNETIC LONGITUDE
MAXIMUM EUV EMISSIONS
MAG. LATITUDE
MAGNETIC LONGITUDE

FIGURE 8

minimum B equator, which provides strong evidence in support of an origin of these protons in the Earth's ring current, and indicates that the particle energies extend to the MeV range. Further study of these precipitating protons can reveal additional information on the state of the ring current and on the mechanisms of particle precipitation.

The South Atlantic Anomaly is another important area of particle precipitation since it is during SAA passes that low altitude spacecraft accumulate most of their radiation dose. The proton and electron components of the SAA are well known (from measurements in previous epochs) but the question of heavier particles is more controversial. Using the ONR-602 monitor telescope, we have examined the SAA region, and the preliminary results show enhanced counts in the MM and MH rates as well as the ML rate, with all these rates showing a change following the large DST excursion about day 250 of 1982. This argues that the MM and MH rates are indeed observing trapped particles rather than a constant background counting rate.

However, before concluding that helium or heavy ions are being observed in the SAA, the possibility of a SAA induced background in the MM and MH must be explored. It may be possible for the high energy tail of the proton energy spectrum to penetrate the passive shielding, at a large angle, and simulate an MM or MH count. Such a source of background would give a time dependence similar to the proton intensity as observed. Detailed simulations of the instrument construction and operation are necessary to establish the level of importance of such a background mode, and we have initiated such a program of investigaions. The significance of our observations in the SAA will depend upon the detailed results of these background studies.

VII. CRRES Mission Planning:

During the past year we have continued to work with the CRRES SPACERAD Science Team in defining the overall scientific products to emerge from the CRRES mission and to define the data needed in support of the engineering experiments. As noted in the previous section, we have already identified several areas in which ONR-604 on CRRES can make a unique contribution. In addition, a committee consisting of the principal investigator, Dr. David Chenette, Aerospace Corp., and Dr. James Adams, NRL, has been formed to develop the procedures necessary to insure both timely and reliable particle flux data to the Microelectronics Experiment Package and the other engineering experiments. This committee had its first meeting during April, 1985 and its work will continue for the next several months. The committee report will become an integral part of the experiment support for the CRRES mission.

VIII. LITERATURE CITED:

Anders, E. and Ebihara, M., 1982, Geochim. Cosmochim. Acta, 46, 2363.

Berko, F. W., Cahill, L. J. Jr. and Fritz, T. A., 1975, J. G. R., 80, 3549.

Black, D. C., 1983, Ap. J., 266, 894.

Cameron, A. G. W., in "Essays in Nuclear Astrophysics" eds. C.A. Barnes, D. D. Clayton, and D. N. Schramm, (Cambridge, 1982, Cambridge Univ. Press). p. 23.

Dietrich, W. F., and Simpson, J. A., 1979, Ap. J. Letters, 231, L91.

Dietrich, W. F. and Simpson, J. A., 1981, Ap. J. Letters, 245, L41.

Evenson, P., Meyer, P. and Pyle, K. R., 1983, Ap. J., 274, 875.

Heikkila, W. J., 1971, J. G. R., 76, 1076.

Hovestadt, D., Hausler, B. and Scholer, M., 1972, Phys. Rev. Letters, 28, 1340.

Krassovsky, V. I., Galperin, Yu. I., Jorjto, N. V., Mularchik, T. M. and Boyunova, A. D., in Space Research, ed. P. Muller (Amsterdam, 1964, North Holland Publishing Co.), p. 572.

Meier, R. R. and Weller, C. S., 1975, J. G. R., 80, 2813.

Mewaldt, R. A., Spalding, J. D., and Stone, E. C., in "Proceedings of the 18th International Cosmic Ray Conference," (Bombay, India, 1983, Tata Institute of Fundamantal Research), 4, p. 42.

Moritz, J., 1972, Zeitschrift fur Geophysik, 38, 701.

Scholer, M., Hovestadt, D. and Gregor, M., 1975, J. G. R., 80, 80.

Tinsley, B. A., 1976, J. G. R., 81, 6193.

Tinsley, B. A., 1979, J. G. R., 84, 1855.

Voss, H. D., Imhoff, W. L., Mobilia, J. and Gaines, E. E., 1984, XXV COSPAR, Graz, Austria.

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